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Structures in the Southwestern Border of the Adamello Intrusion (Alpi Bresciane, Italy)

by *Peter Brack* *)

Abstract

Pre-existing, large-scale folds in the Lower to Middle Triassic carbonates and pelites of the M. Frerone area have been cut and deformed by a succession of Eocene intrusions. Earlier small-scale intrusions of diorites and tonalites heated up the rocks of the region and caused the first contact metamorphism of the sediments together with an inversion of the original viscosity contrast between the calcareous and pelitic rocks. Deformation of the M. Frerone anticline was synchronous with later intrusions of large tonalite bodies.

Genetic analogies of small-scale folds of the M. Frerone area with comparable structures to the west of Val Camonica and the regional structural pattern suggest a relationship of the structures on the southwestern border of the Adamello intrusion with the thrustsheet and fold tectonics of the eastern Bergamasc Alps, which are earlier than, and independant of the first Eocene intrusions.

Riassunto

Preesistenti pieghe a larga scala nei carbonati e nelle peliti della regione del M. Frerone (Trias inferiore - medio) sono state penetrate e deformate da una successione di intrusioni di età eocenica. Piu antiche intrusioni a piccola scala di dioriti e tonaliti avevano riscaldato le rocce della regione, causando il primo metamorfismo di contatto dei sedimenti insieme con un'inversione dell'originario contrasto di viscosità fra rocce calcaree e pelitiche. La deformazione dell'anticlinale di M. Frerone è stata sincrona con la successiva intrusione di grandi corpi tonalitici.

Le analogie genetiche fra le pieghe a piccola scala della zona di M. Frerone e le corrispondenti strutture a ovest della Val Camonica insieme con la configurazione strutturale regionale permettono di individuare una relazione esistente fra le strutture del margine sud-occidentale dell'intrusione dell'Adamello e la tettonica a pieghe e scorrimenti delle Alpi Bergamasche orientali, la quale è perciò di epoca più antica e indipendente dalle primi intrusioni eoceniche dell'Adamello.

Zusammenfassung

Ein grossräumiges Faltenmuster in den unter- bis mitteltriadischen Karbonaten und Peliten im Gebiet des M. Frerone ist durch eine Abfolge von mehreren eocänen Intrusionen abgeschnitten und

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deformiert worden. Frühere kleine Intrusionen von Dioriten und Tonaliten haben das Gebiet aufgeheizt und mit einer ersten Kontaktmetamorphose eine Umkehrung des ursprünglichen Viskositätskontrastes zwischen den karbonatischen und tonigen Gesteinen bewirkt. Deformationen der M. Frerone Antiklinale und der Kleinstrukturen sind hauptsächlich von Intrusionen späterer grosser Tonalitmassen verursacht worden.

Genetische Analogien von Kleinstrukturen am M. Frerone mit entsprechenden westlich der Val Camonica und das regionale Strukturmuster lassen einen Zusammenhang der Falten am Adamellosüdrand mit der östlichen Bergamasker Falten- und Deckentektonik erkennen, welche älter und unabhängig von den eocänen Intrusionen ist.

I. Introduction

The tertiary plutonic rocks of the Adamello intruded the cristalline basement and sedimentary cover of the Southern Alps. BIANCHI et al. (1970) have divided the Adamello intrusion into different lithological units and have interpreted these as individual large plutons. The intrusive rocks in the southwest belong to the M. Re di Castello pluton and are the oldest among all the Tertiary acid plutonic rocks in the Adamello batholith (45–41 my, Rb/Sr Biotite ages, Granodiorite and Pegmatite, FERRARA 1962).

BIANCHI/DAL PIAZ (1937), COLBERTALDO (1940), ACCORDI (1953), MALARODA (1954) and MORGANTE (1972) have geologically and petrographically investigated selected areas in the north of Pso. Croce Domini. The emphasis of their studies is primarily upon the description of the diverse intrusive rocks. Taking into account more recent comprehensive studies on the plutonic rocks (BIANCHI et al. 1970, CALLEGARI/DAL PIAZ 1973) and the presently well investigated stratigraphy in the area of Val Camonica and Giudicarie, we have started new mapping of the intrusive and country rocks to the east and north of Breno. Therewith we intend to examine the relationships among the intrusive rocks as well as the deformation of the nearby country rocks.

As can bee seen in Fig. 1 the syncline of Pzo. Badile, first recognised by SALOMON (1908), extends to the western flank of Val Camonica (directly to the west of the village Losine). The fold axes strikes N80E and is more or less horizontal in the bottom of the valley. This syncline, as well as the Cedegolo anticline in the north, suggests a direct tectonic continuity across the valley. Such a continuity is contrary to previous interpretations (ERDMAN 1939, ACCORDI 1953). The large-scale folds to the south of Badile syncline have not been found on the west side of the valley, where only the Calc. di Angolo formation outcrops, with strongly developed small-scale internal folds (Fig. 3).

The fold patterns are related to the fold and thrust sheet (?) tectonics of the eastern Bergamasc Alps (DE SITTER 1949) and can be followed to the southern border of the Adamello batholith. Upper Eocene - Oligocene ages for comparable structures in the central Bergamasc Alps have been assumed from indirect evidence in the Southern Alpine Molasse (GAETANI/JADOUL 1979).

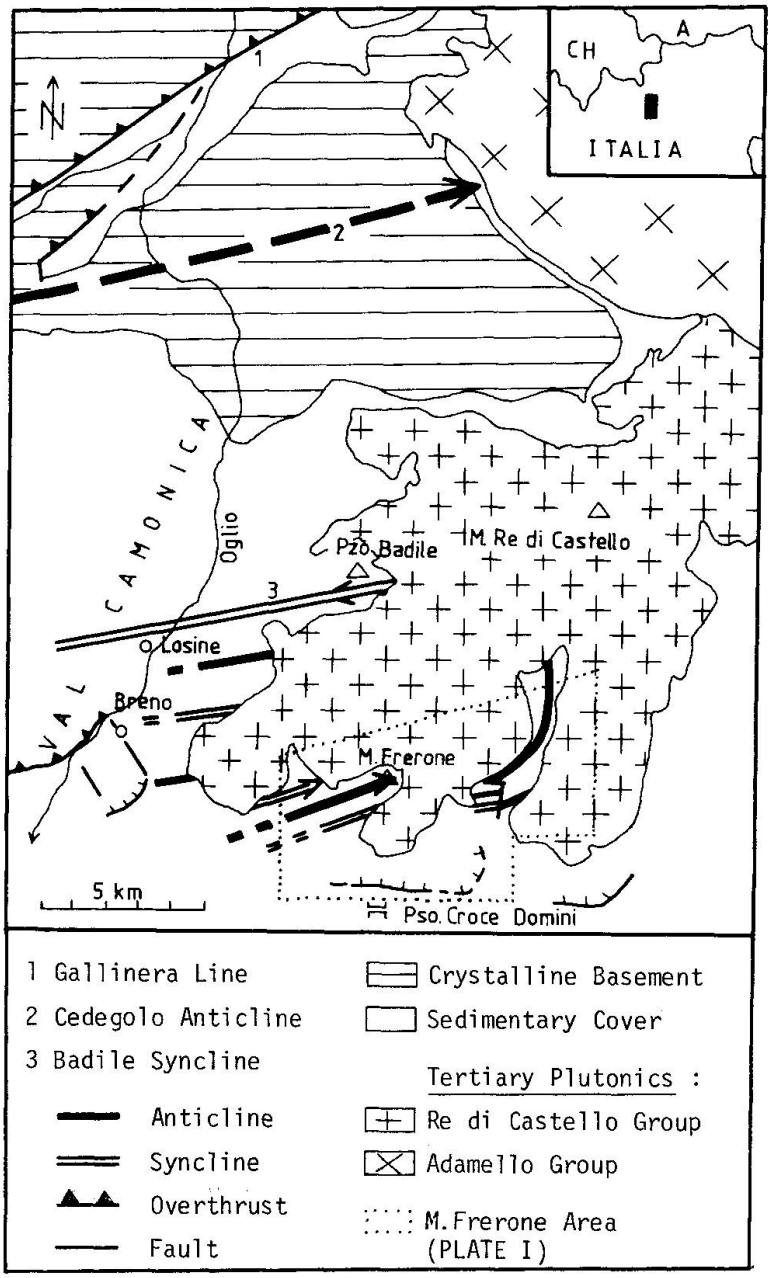


Fig. 1 Tectonic sketch of the middle Val Camonica area.

II. Geological Setting

The plutonic rocks of the M. Frerone area (Plate I) are in direct contact with Lower to Middle Triassic carbonate and pelitic rocks. In this area the shallowest level magmatic rocks of the Adamello batholith are exposed. There are an extraordinary number of dykes of different generations related to the multiple high plutonic character of the intrusives.

A brief lithological description of the predominant rock types is given below (see Map, Plate I).

A. MAIN INTRUSIVE ROCKS

The rock names given refer to names used in literature, while petrographic names in the description follow the classification of STRECKEISEN (1967).

1. «Diorites and Gabbros»

This group comprises gabbroic to dioritic melanocratic and hornblenderich rocks. The largest body outcrops in the Cne. di Blumone over an area of at least one square kilometer. On M. Cadino (SCHELLHORN 1980) these rocks are continuously gradational into ultrabasic olivine-pyroxene-hornblendites to the northeast of M. Mattoni (SONDEREGGER 1980).

2. «M. Re di Castello Tonalites»

Leucocratic biotite-hornblende-tonalites outcrop in the north of the area studied and belong to the separated southern large mass of the so called M. Re di Castello tonalite (CALLEGARI/DAL PIAZ 1973).

3. «Val Fredda Leucoquartzdiorite»

A small intrusion of a light-coloured, porphyritic biotite-tonalite with little hornblende is clearly distinguishable from the other tonalites in Val Fredda and south of M. Frerone. This rock has been termed «Val Fredda Biotite-Leucoquartzdiorite» by BIANCHI et al. (1970).

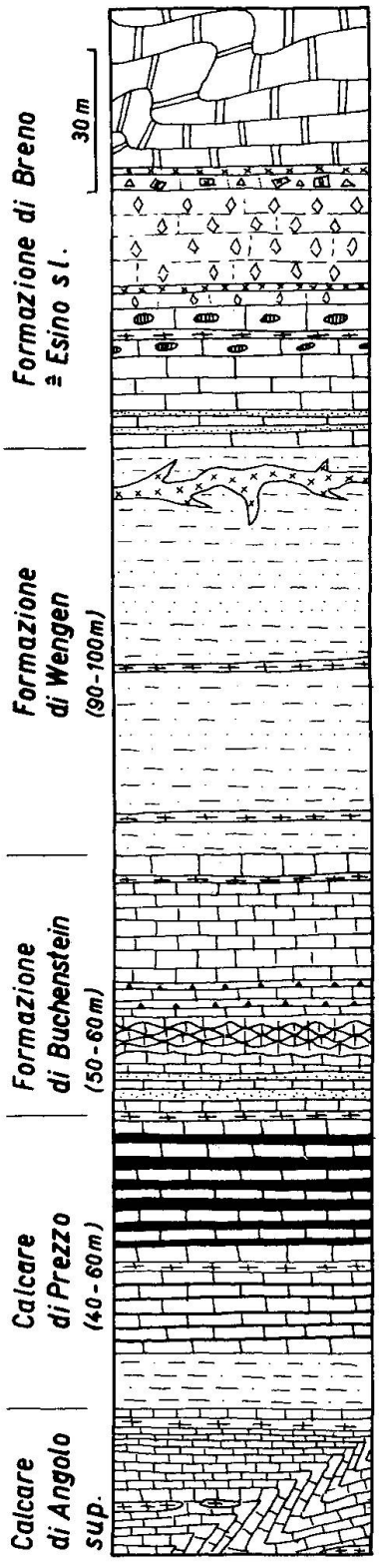
4. «Bruffione Granodiorite»

This unit comprises a more-or-less homogeneous biotite-hornblende-granodiorite, with variable proportions of biotite and hornblende. Towards north and northwest it separates the two large masses of the M. Re di Castello tonalite (CALLEGARI/DAL PIAZ 1973).

Age relationships of the intrusive rocks

Diorites and Gabbros represent the earliest intrusive rocks in the series and are present as large xenoliths in the tonalitic rocks as well as small intrusions in the sediments at other places (Pzo. Badile area). The leucocratic rocks commonly contain xenolith-swarms of the mafic rocks, which grade into intrusive breccias (agmatites) towards the contact between leucocratic and mafic bodies. The diorites and gabbros are possibly of Lower Eocene age (BORSI et al. 1977).

On grounds of structural interpretation (presented below) the small Val Fredda intrusion must be older than the M. Re di Castello Tonalites but must have deformed plastically at the time of the later intrusion.



			NON METAMORPHOSED EQUIVALENT
a	a	sugar-grained dol-marbles with thin folded Cc-Ol-layers	massive dolomites with local cherty intercalations
o p	b	brown-yellow often brecciated porous Cc-marbles	cornieule
b			
o c n	c	light Cc-marbles with chert nodules	irregularly bedded limestones with chert nodules
	d	coarse-grained white and brown Cc-marbles with rusty weathered surface hornfels (20 to 50 cm thickness)	well stratified limestones alternating with marls in the lower part
d			
o	e	violet-brown massive splintery hornfels with indistinct bedding	homogeneous marls to shales poorely stratified (?"argillite di Lozio")
e	f	light, platy Cc-marbles in 2 to 10 cm thick beds, separated by thin boudins of hornfels	regular well stratified limestones with marly intercalations (?"Calc. di Pratondo", ROSSETTI 1966)
n			
	g	violet, 3 to 8 cm thick hornfels	? green volcanic tuff ("pietra verde")
n	h	nodular Cc-Woll-marbles with Qz-rich green hornfels-like borders and intercalations	nodular limestones, nodules bounded by cherty envelopes
n f			
g	i	regular alternation of light Cc-marbles and rusty hornfels (5 to 20 cm thick)	thick black limestones regularily alternating with dark marls and shales
h i n	k	conspicuous alternation of dark limy hornfels and light blue Cc-marbles	
k	l	splintery dark limy hornfels	black unstratified marly shales
n	m	regular, folded thin bedded alternation of grey Cc-marbles and brown to black hornfels	monotonous sequence of thin bedded limestones, planar to nodular, well separated by marls
l n	n	acid porphiric sills (0.5 to 1 m thick), often boudinaged and overprinted by a contact metamorphism (early or pre-Adamello intrusions)	
m	o	small fine-grained irregular diorite intrusions	
n	p	late tectonic breccia with diorite- and sediment-components	

Cc: calcite/Dol: dolomite/Ol: olivine/Woll: wollastonite/Qz: Quartz

Fig. 2 Stratigraphic profile from the M. Frerone (W-flank, N-ridge).

The relative age between the Bruffione Granodiorite and the tonalitic intrusions can not be precisely determined from the presently known structural relationships.

B. SEDIMENTS

A complete stratigraphic section of the sediments (Fig. 2), ranging from Middle Anisian to Carnian, is exposed on M. Frerone. Even though these rocks are in part strongly affected by contact metamorphism, distinct lithological differences are preserved allowing definite stratigraphic correlation. Except in the Calc. di Angolo and the upper Esino (s. l.) the bed thicknesses in this profile are essentially neither tectonically reduced nor thickened.

The stratigraphic profile in Fig. 2 has been used as reference for the whole contact-metamorphic overprinted zone. The significance of the dolomites and limestones of the M. Colombine block (Plate I) is not yet clear. SALOMON (1908) presumed an Anisian reef-facies, but these rocks could just as easily be interpreted as comprising Esino (s. l.) lying tectonically over the Lower Triassic rocks.

III. Structural Relationships

A. LARGE SCALE STRUCTURES

The intrusive rocks postdate a clearly defined deformation in the sediments. In a narrow zone bordering the main intrusive bodies, a later deformation has overprinted the pre-intrusive structures.

Pre-Intrusive Deformation (Phase I)

The earliest structures in the area are characterised by large-scale folds with subhorizontal fold axes and originally steeply northwards dipping axial surfaces which strike N60-80E, such as the large anticline-syncline pair on M. Costone and M. Frerone as well as the Badile syncline in Val Camonica. Several of these earlier folds also occur in Val Caffaro.

Syn-Intrusive Deformation (Phase II)

The large-scale structures of Phase I are cut and deformed by the Middle to Upper Eocene intrusive rocks which contain the diorites and gabbros of possible Lower Eocene age. The true «intrusive deformation» in the sediments (Phase II) has been caused above all by the intrusion of the M. Re di Castello Ton-

alites in the north and the Bruffione Granodiorite intrusion in the east, and is characterised by an extremely plastic deformation of the carbonate rocks.

In the upper Val Caffaro the trend of the axial plane of the large-scale folds have been rotated approximately 60° counterclockwise from their original orientation (Plate I). The originally subhorizontal fold axes rise steeply towards the head of the valley, at least 600 meters over a horizontal distance of 3 km. The folds have often been compressed into isoclinal folds with tectonically thinned limbs and are cut by vertical faults. Locally, the large-scale fold axes are cut and deformed by the intrusions and generally plunge towards the intrusive contacts, for example the northeastern termination of the M. Frerone anticline (Plate I).

In the west of the area studied, the limbs of the M. Frerone anticline have been compressed to form a complex pattern of folds with steep axes («schlingen structures»). The neighbouring Val Fredda intrusion shows a conspicuous orientation of dicus-like basic and sedimentary xenoliths with their long and intermediate axes parallel to the contact to the M. Re di Castello Tonalites.

B. SMALL SCALE STRUCTURES

The uniformly thinnly-interbedded Anisian limestone-marl series of the Calc. di Angolo superiore have been intensively folded during the two phases of deformation. Either refolded axial surfaces or compressed primary structures may occur, depending upon the original orientation of the Phase I folds to the main Phase II stress directions.

Proposed Model for the Development of the Small Scale Structures in the Calc. di Angolo (M. Frerone)

By a comparison of the folds in the metamorphosed Calc. di Angolo (Fig. 4) with those in the non-metamorphosed equivalent from the eastern Bergamasc fold and thrust sheet area (Fig. 3), a schematic development of the small-scale folds in the M. Frerone area can be shown (Fig. 5).

A model for the transformation of regularly bedded multilayer sequences to plane strain chevron folds with no displacement perpendicular to the profile section has been presented by RAMSAY (1974). In the area to the west of Val Camonica, interlimb angles of the chevron folds average 50° (Fig. 3). Special structures such as hinge collapse, bulbous hinge structures and limb thrusts can be observed (see also Fig. 8, RAMSAY 1974).

Contact metamorphism has resulted in a recristallization to hornfels and calcite-marbles and has caused an inversion of the original viscosity contrast. The fold profile has been further coaxially compressed during the second phase

Fig. 3 Chevron folds in the non-metamorphosed Calc. di Angolo along the road Malegno–Lozio (eastern Bergamasc Alps).

Fig. 4 Coaxial compressed (after metamorphism) folds of the same type as in Fig. 3. For explanations see Fig. 5 and text.

of deformation (Phase II). Thereby the strain pattern no longer remained that of plane strain and the folds became modified towards similar-fold form. The interlimb angles have decreased to approximately 30°. Relicts of the above mentioned special hinge structures can still be recognised. Hornfels layers have often been broken and show boudin structures. A detailed study of the «chocolate-tablet» boudinage of the Calc. di Angolo in the same region has been presented by GOGUEL (1948).

C. INTERPRETATION

As can bee seen from Fig. 5 the Phase II deformation must have taken place after the hornfels development. The calcite marbles as well as dolomites in other places show a very plastic behaviour pattern. From the experimental studies of HEARD (1976) we can assume relatively high temperatures existed during the second deformation phase. These observations together with parallelism of the flattening planes of the discoid basic and sedimentary inclusions in the Val Fredda pluton to the contact with the M. Re di Castello Tonalites, suggest that the diorites and the Val Fredda Leucoquartzdiorite represent earlier small in-

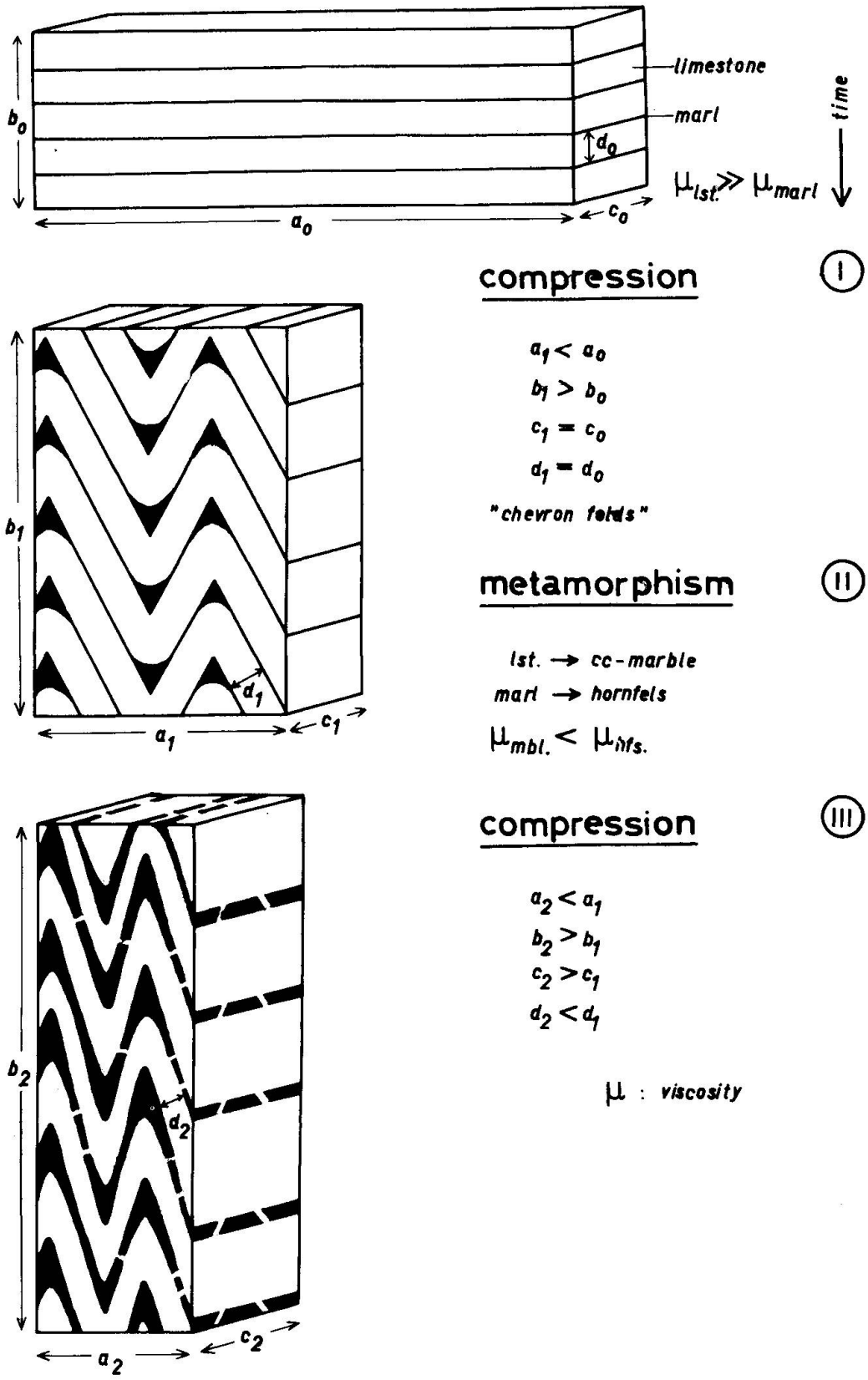


Fig. 5, a, b, c Model for the Development of the Small Scale Structures in the Calc. di Angolo (M. Frerone).

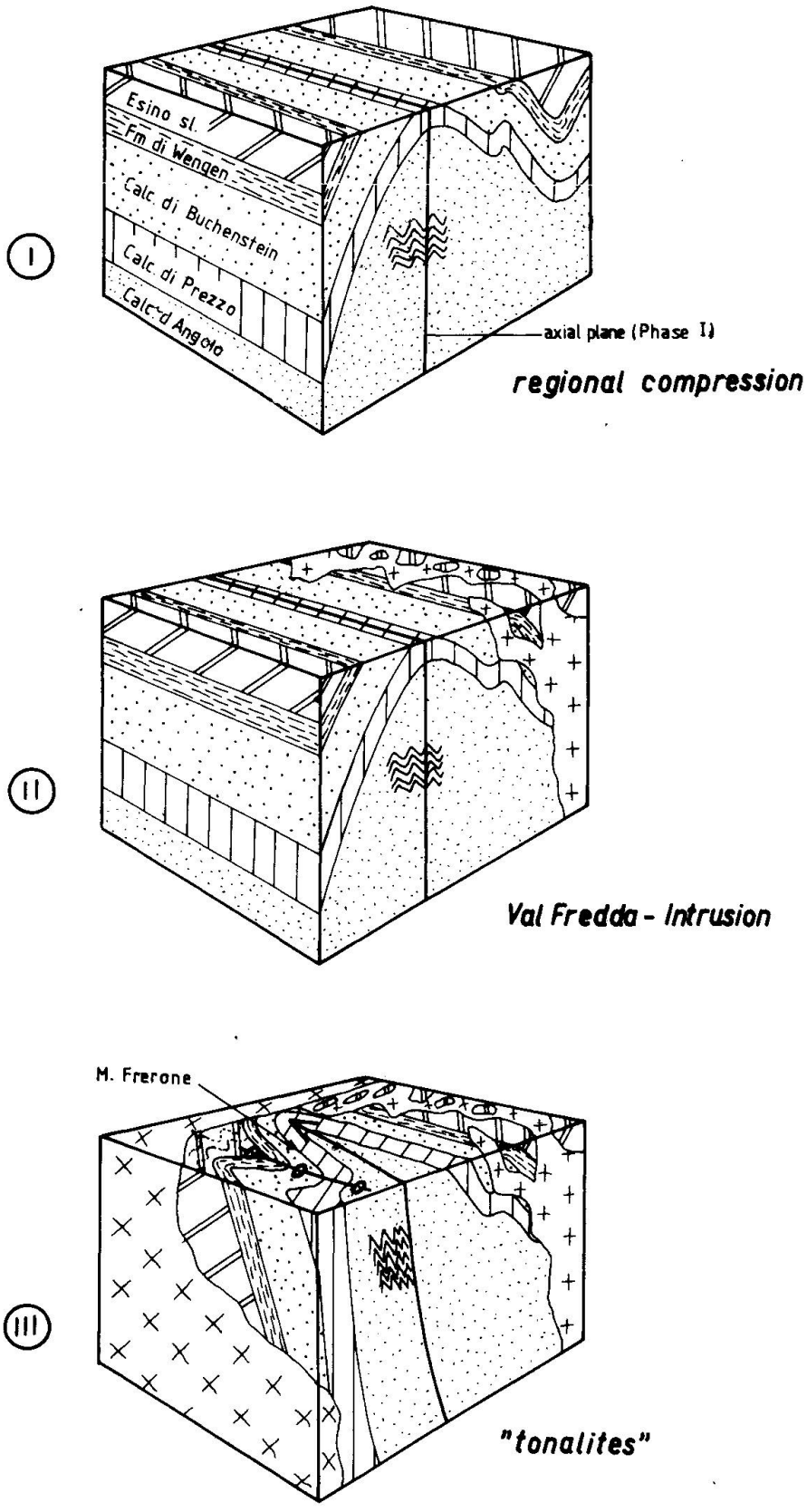


Fig. 6 Tectonic development of the M. Frerone area.

trusions that heated up the region and caused the first contact metamorphism. The later intrusion of the M. Re di Castello Tonalites inhomogenously deformed the M. Frerone anticline limbs and probably caused the deformation in the border zone of the Val Fredda intrusion. This tectonic development is schematically summarised in a block diagram (Fig. 6).

IV. Discussion

The most recent re-mapping of the area to the north and east of Breno has led to the following conclusions:

A. The succession of the main intrusive masses in the area north of Pso. Croce Domini was as follows:
1. Diorites and Gabbros
2. Val Fredda Leucoquartzdiorites
3. Re di Castello Tonalites

The age relationship of the Bruffione Granodiorite is still uncertain.

B. Pre-existing large-scale structures have been cut and deformed by the Eocene intrusions of the area.

C. A two-phase deformation pattern has also been recognised in the small scale structures. The reasons of deformation for both the large and small-scale structures are probably identical.

D. The pattern of WSW–ESE striking folds in Val Camonica (Fig. 1) suggests a regional compression in a NNW–SSE direction, which was earlier and independant of, the first Adamello intrusions.

This first comparison of the small-scale structures of the M. Frerone with corresponding ones in non-metamorphosed series of the eastern Bergamasc Alps, together with the structural continuity of both valley flanks in Val Camonica shows that the regional deformation is pre-intrusive and therefore older than 45 my (FERRARA 1962). This age limit will be modified as soon as a definite age for the Diorites and Gabbros is known.

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